National Bureau of Standards

TECHNICAL NEWS BULLETIN

VOLUME 35 AUGUST 1951 NUMBER 8

NBS Magnetic Attenuator

An inexpensive type of microwave attenuator for coaxial transmission lines recently developed by Frank Reggia of the National Bureau of Standards utilizes a magnetic field to obtain instantaneous changes in attenuation. The new device, an outgrowth of NBS research in power-measuring techniques at microwave frequencies, is known as a magnetic attenuator. Its operation depends on the interaction between the electromagnetic field within a transmission line, which contains microwave-energy-dissipating material, and an external magnetic field applied perpendicularly to the axis of the line. As a result of this interaction, the loss characteristics of the dissipative material are substantially altered. The NBS Magnetic Attenuator requires no movable components, mechanical controls, or slotted sections in the transmission line and may be operated either manually or automatically from a proximate or remote position.

Attenuators used at microwave frequencies have multiple purposes such as adjusting power levels, isolating monitoring equipment, or padding an oscillator from variations in the load. However, their use has generally been complicated by control inaccuracies and mechanical inflexibility.

In conventional microwave attenuators, the energy is usually dissipated in an element made of resistive film on glass or Bakelite, powdered carbon, or polyiron materials having characteristics that vary with length, composition, and operating frequency. The dissipative element must often be carefully machined to close tolerances and is usually very fragile. Additional difficulties arise when variable attenuation is required in a transmission line circuit. Complex mechanisms, which are necessary to insure a high degree of precision and fineness of control, usually result in bulky, hard-to-handle controls at substantially increased costs.

In designing the NBS Magnetic Attenuator, efforts were made to avoid many of the disadvantages encountered in conventional attenuators. The unit is simple in construction; it is composed only of a slug of some highly permeable and resistive ferromagnetic material placed within the field of an electromagnet. The significant feature of the device is the change in the loss properties of the dissipative material when it is subjected to a magnetic field. Because the magnetic field is produced by an electromagnet, its magnitude can be changed simply and precisely by varying the current in the field coils. Consequently, the permeability and loss characteristics of the dissipative material are controlled, and a variable attenuator results. In addition, the control characteristics are linear over a substantial range. An NBS investigation of materials such as polyiron and ferrites (with electrical resistivities from 10^6 to 10^7 ohms per centimeter) indicated that the loss characteristics not only depend upon the composition and length of the material but increase with increasing frequency.

The size of an NBS Magnetic Attenuator for $^3/_8$-inch coaxial transmission lines is only 4 by 4 by 2 inches. The dissipative material, a cylinder of polyiron, is about $^1/_2$ inch long and $^3/_8$ inch in diameter. A recessed conductor hole for the center conductor is drilled into the cylinder, ceramic insulators are placed at the extremities, the whole assembly is encased in a metal sheath,

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U. S. DEPARTMENT OF COMMERCE

CHARLES SAWYER, *Secretary*

NATIONAL BUREAU OF STANDARDS
E. U. Condon, *Director*

AUGUST 1951 Issued Monthly Vol. 35, No. 8

For sale by the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C. Subscription price, domestic, $1.00 a year; foreign, $1.35; single copy, 10 cents. The printing of this publication has been approved by the Director of the Bureau of the Budget, February 3, 1950.

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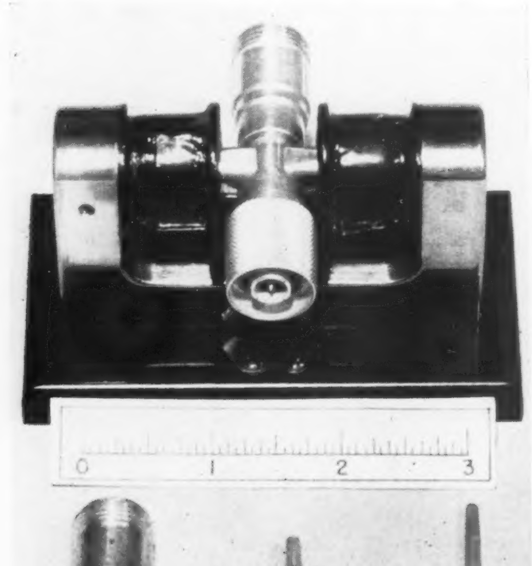
and connector pins are fastened to the ends of the center conductor. Standard male and female type N coaxial connectors complete the assembly.

The electromagnet requires a direct-current power source of 0 to 250 volts with a maximum of 30-milliamperes current to produce a magnetic field of 1,500 gauss in the air gap. Small changes in the magnetic field are obtained by controlling the field current with a multi-turn Helipot potentiometer.

An experimental model of the NBS Magnetic Attenuator that uses polyiron as the dissipative element was operated at frequencies from 1,000 to 3,000 Mc. Variations in the losses of the polyiron were produced that were large enough to reduce the attenuation 60 percent, change the power by a ratio greater than 60:1, with a voltage standing-wave ratio always less than 1.5.

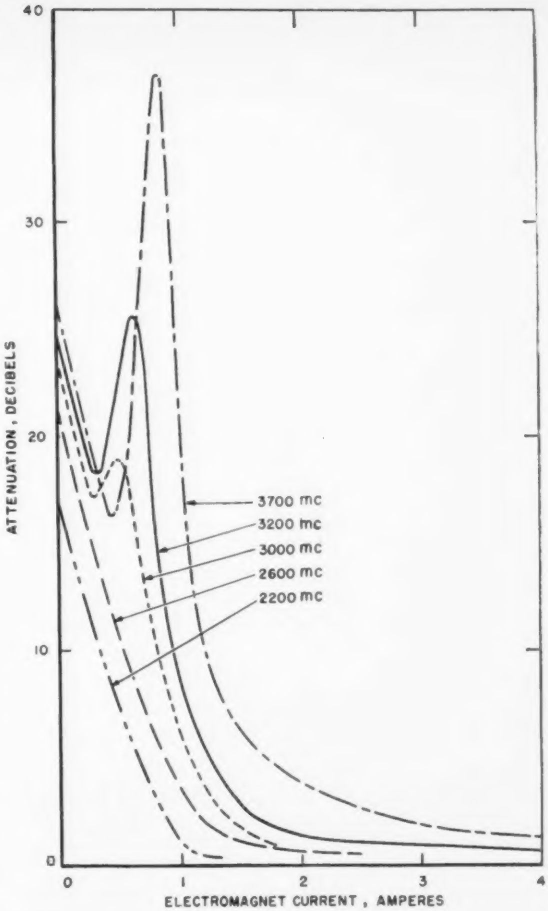
More recently, a study was made at NBS of an attenuator that employs a slug of Ferramic B ½ inch long and ⅜ inch in diameter as the dissipative medium. The dependence of the losses in the material on frequency was remarkably demonstrated by this experiment. At 2,200 Mc the attenuation was reduced from 17 decibels to less than ½ decibel, and less than 45 milliamperes of current was required to maintain the magnetic field. At a frequency of 2,600 Mc, changes in attenuation greater than 20 decibels were obtained with the same electromagnet currents. To avoid saturation in the iron core of the small, low-current electromagnet, a larger unit was used to obtain greater changes in attenuation. At several frequencies, attenuation changes in excess of 95 percent have been obtained without difficulty.

While operating at a frequency of 3,200 Mc, a striking example of ferromagnetic resonance was exhibited. As the electromagnet current was increased, the attenuation decreased from its initial value of 24 to about 18 decibels, then peaked to about 25, and finally decreased to approximately 1 decibel. The peak occurred at a current of approximately 0.6 ampere. When operating at 3,700 Mc, a similar phenomenon occurred. The initial attenuation of 26 decibels was reduced to about 16 before peaking to 37 decibels; finally it dropped to about 1 decibel as the current continued to increase.



The NBS magnetic attenuator is separated into its essential components: (left) Complete housing with type *N* connectors; (center) metal sleeve enclosing the elements and connector pins; (right) exploded view of inner components showing the slug or cylinder of microwave-energy dissipating material, ceramic spacers, and connector pins.

Graph of attenuation versus electromagnet current of an NBS magnetic attenuator using Ferramic B as the dissipative medium to microwave energy. The curves strikingly display the effect of ferromagnetic resonance as the operating frequency is increased. In this particular attenuator, the dissipative material is ½ inch long and ⅜ inch in diameter.



The resonance effect appeared when the electromagnet current was approximately 0.8 ampere.

When the magnetic field is rotated 360 degrees about the axis of some of these coaxial attenuators, a position may exist where the field has its maximum effect. For instance, when a magnetic field of constant intensity was rotated about the axis of the above coaxial attenuator operated at 3,700 Mc, changes in attenuation of 17 decibels were obtained. However, this rotational phenomenon does not exist for all materials used in these attenuators.

Many applications of this magnetic phenomenon are immediately evident. An audio source can be used to vary the electromagnet current, which produces a changing field in the attenuator and consequently amplitude-modulates the radio-frequency signal. The resultant modulation envelope includes the predominant second and higher harmonic frequencies of the audio-frequency field. However, these harmonics can be readily eliminated by employing a direct-current bias about which the alternating-current field oscillates. The use of the NBS Magnetic Attenuator in this fashion permits amplitude modulation of UHF and microwave oscillator outputs without the frequency modulation effects that occur when the oscillator is modulated directly.

The NBS Magnetic Attenuator is equally adaptable as an output stabilizer for microwave oscillators. The unit can be part of a degenerative feedback circuit in which the magnitude of the field produced by the electromagnet is controlled by a small amount of radio-frequency power taken from the coaxial transmission line. Another magnetic unit may also be utilized in such a feedback network. The rectified control voltage coupled from the transmission line may be applied to a magnetic amplifier which controls the electromagnet field directly.

Current NBS investigations are being directed toward finding better and more efficient dissipative materials. Among the latest group of materials under study are magnetic ferrites, which yield greater attenuation changes for a given electromagnet current than does polyiron. These ferrites should thus make possible the use of smaller currents to produce the same changes of attenuation.

A waveguide attenuator using similar principles is described in Magnetically controlled waveguide attenuator *by Theodore Miller, J. Appl. Phys.* **20**, *878 (1949).*

Determination of Rubber Hydrocarbon by Measurement of Refractive Index

A simple, rapid method for the quantitative determination of rubber hydrocarbon in crude natural rubber has been developed by Rachel J. Fanning and Norman Bekkedahl of the NBS rubber laboratory. As the new method requires only the measurement of refractive index of a solution containing a known weight of rubber in a known weight of solvent, a single operator can make a large number of separate determinations in a short time. The NBS procedure is thus expected to find application in the rubber industry for the evaluation of crude rubber, especially where the lower grades are used.

In addition to rubber hydrocarbon, crude natural rubber contains moisture, resins, proteins, ash, and other minor constituents. Although most of the better grades of rubber prepared on plantations contain from 93 to 96 percent of rubber hydrocarbon, the lower grades of plantation rubber as well as many types of

The percentage of rubber hydrocarbon in crude natural rubber is accurately determined by measuring the refractive index of a solution of the rubber in 1-bromonaphthalene. The simplicity of the new NBS method should make it readily adaptable to industrial operations.

"wild" rubber may contain much lower percentages—in some cases as little as 70 percent or even less. Because of this great variation in the nonrubber constituents, which can largely be considered as inert material, the hydrocarbon content of natural rubber must be known in order to evaluate it for processing and use.

While several methods have been available for the determination of rubber hydrocarbon, none has proved entirely satisfactory. For example, cumulative errors decrease the accuracy of the method of "differences", in which the nonrubber constituents are first determined quantitatively and their total percentage then subtracted from 100. The only two direct procedures currently in use, the chromic acid oxidation method and the rubber bromide method, involve chemical reactions and require empirical correction terms in the calculation of the results from the data. All three of these methods require a large amount of chemical apparatus and extensive manipulation. The new refractive-index method, on the other hand, employs no special apparatus other than a refractometer. It makes use only of physical processes and thus involves only measured physical constants and no correction terms.

In the NBS method, a small sample of the crude rubber is first cut into small pieces and weighed. It is next treated with acetone to remove resinous material. After drying in a vacuum oven for about an hour at 100° C, it is again weighed and dissolved in 1-bromonaphthalene. The resulting solution is made complete and uniform by heating with intermittent stirring for 2 hours at 140° C. After cooling, the solution is weighed and its refractive index measured. From the observed data and from the known densities and refractive indices of pure solvent and rubber hydrocarbon, the percentage of rubber hydrocarbon in the sample is computed.

This procedure is based on two assumptions. The first is that all material remaining in the acetone-extracted rubber, with the exception of the rubber hydrocarbon, is insoluble in the bromonaphthalene and consequently has no influence on the refractive index of the solution. The second assumption is that the refractive index of a solution of rubber hydrocarbon in a solvent is a linear function of the volume percentage of the rubber hydrocarbon in solution. Both assumptions appear justified by results of a large number of measurements on various samples of natural rubber including plantation rubber, purified rubber, and a variety of wild rubbers.

Assuming a straight line would be obtained by plotting refractive index of the solution against the volume percentage of rubber hydrocarbon present in the solution, the ratio of any two differences along one axis can be set equal to the ratio of the corresponding differences along the other axis. Specifically, the ratio of the volume of rubber hydrocarbon to the volume of solvent in the solution can be equated to

$$\frac{n_s - n_M}{n_M - 1.5190}$$

where n_s is the refractive index of the solvent, n_M is the observed refractive index of the rubber bromonaphthalene solution, and 1.5190 is the refractive index (sodium D line at 25° C) of natural rubber hydrocarbon as recently determined at NBS. The weight percentage of rubber hydrocarbon in the original rubber sample is then obtained from the equation

% rubber hydrocarbon =

$$\left(\frac{M-E}{D}\right)\left(\frac{n_s - n_M}{n_M - 1.5190}\right)\left(\frac{0.9060}{R}\right)100$$

where M is the total weight of extracted rubber and solvent, E is the weight of extracted rubber in the mixture, D is the density of the solvent, R is the weight of the sample of crude rubber before extraction with acetone, and 0.9060 is the known density of rubber hydrocarbon in grams per cubic centimeter at 25° C.

In studies of the method at the NBS, samples were analyzed ranging from partially purified rubber having a rubber hydrocarbon content of about 99 percent to some wild rubbers containing only about 80 percent rubber hydrocarbon. In general, the precision of the refractive index method has been found to be about the same as that of the rubber bromide method and somewhat higher than the chromic acid oxidation method. However, an advantage of the chromic acid method over the other two is that it can be applied to either unvulcanized or vulcanized rubber and also to mixtures of natural and synthetic rubbers. This is not true of either the refractive index or the rubber bromide method, which are applicable only to unvulcanized natural rubber.

Air-Gravel Concrete

A lightweight concrete recently developed by R. C. Valore, Jr., and W. C. Green of the NBS structural engineering laboratory substitutes air bubbles for sand. Suitable for the construction of monolithic walls and other elements of small structures, this "air-gravel concrete" grew out of a request from the U. S. Bureau of Plant Industry, Soils, and Agricultural Engineering for a material particularly adaptable to farm buildings. The many tiny air bubbles enclosed within the material not only replace the sand used in ordinary dense concrete but also make the product lighter in weight, a better insulator against heat or cold, and more resistant to water penetration.

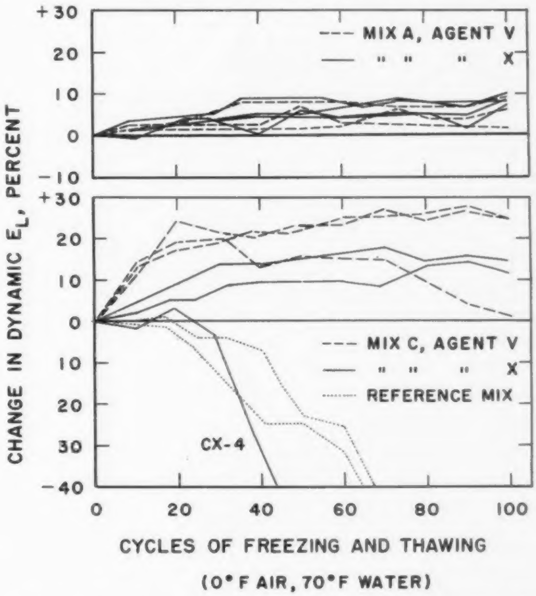
Concrete normally contains a coarse aggregate such as gravel or crushed stone held together by a binder of mortar consisting of sand and cement-water paste. In the air-gravel concrete the fine aggregate or sand is replaced by air bubbles, which act as a "lubricant" and produce a very workable mixture. High-air-content concrete is prepared in conventional mixing equipment in the normal way, except that an industrial aerating agent or a detergent is added to the mix to cause it to foam by entraining finely divided air cells in the cement-water paste. Entrained air may constitute up to 45 percent of the volume of the concrete prepared at the Bureau, and "pea gravel" forms the dense aggregate.

One of the important functions of fine aggregate sand in conventional concrete is to produce workability, which facilitates placing in forms and assures homogeneity in structural members. Results of an investigation at NBS indicate that the replacement of conventional fine aggregate by entrained air likewise produces workable mixtures having relatively low water-cement ratios. The mixtures studied consisted of a high-early-strength Portland cement, siliceous pea gravel (No. 4 to 3/8-inch sieve fraction), water, and an air-entraining agent. Two different air-entraining agents (foam stabilizers) were used: agent *V*, a proprietary neutralized resin; and agent *X*, a proprietary sodium–lauryl–sulfate—type detergent. The falling action of the gravel particles during mixing in an ordinary rotating tilt-drum mixer produces the entrainment of air in the cement-water paste, and the air-entraining agent renders the foamed paste stable.

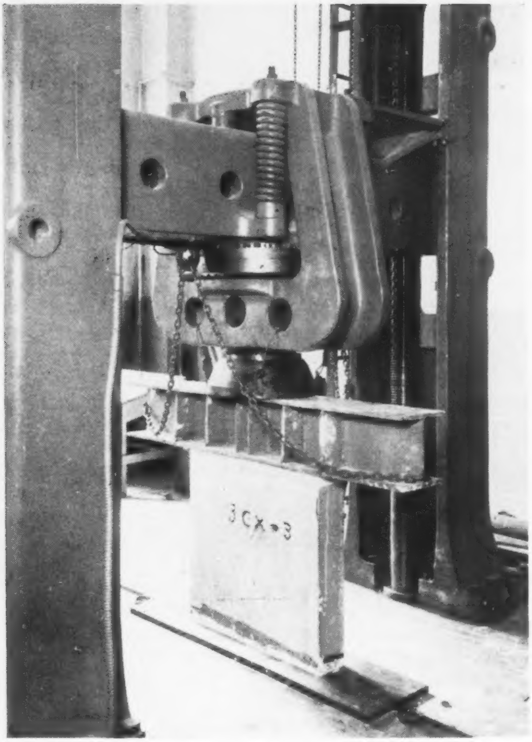
Air contents as high as 45 percent were found possible in concretes containing no sand, while there appeared to be a "ceiling" of about 30 percent in the air content of experimental mixtures containing both sand and gravel. However, the amount of entrained air, upon which the density depends, was limited critically by the minimum compressive strength requirement of 500 pounds per square inch. The lowest cement content permitting the attainment of the required strength in an air-gravel concrete was about 3¼ bags of cement per cubic yard of concrete. In this "lean" mix (mix *A*) it was necessary to maintain an air content of about 25 percent to provide the necessary workability and strength. A second mix (mix *C*), containing about 5.6 bags of cement per cubic yard of concrete, provided the required strength for air contents as high as 29 percent.

The compressive strength was sensitive to variations in air content; an increase of 1 percent in air content was generally accompanied by a decrease of about 100 pounds per square inch in compressive strength for both mix *A* and mix *C*. The indicated density of concretes having a compressive strength at 28 days of 500 pounds per square inch was about 113 pounds per cubic foot for mix *A*, and 105 and 109 pounds per cubic foot respectively for mix *C* concretes made with the resin and detergent air-entraining agents, as compared with 140 to 145 pounds per cubic foot for conventional (nonaerated) sand-gravel concretes. While the compressive strengths were only one-fourth to one-fifth the values obtained for nonaerated concretes, the moisture properties and thermal conductivity of the air-gravel concretes compared favorably with the values obtained for the denser concretes.

The mean water absorption of the lightweight concretes upon soaking for 24 hours at room temperature was about 9 percent (by volume) for all mixes, compared with 11 to 15 percent for conventional concretes of similar materials and cement contents. Saturation coefficients, calculated as the ratio of the 24-hour room temperature absorption to the 5-hour boiling absorption, ranged from 0.22 to 0.36, or about one-third the magnitude of values previously reported for nonaerated sand-gravel concretes. The saturation coefficient purports to represent the ratio of the pore



The effect of cycles of freezing and thawing upon the air-gravel concrete specimens are indicated by plotting changes in Young's modulus of elasticity (longitudinal), E_L, against the number of cycles of freezing and thawing.



Compressive-strength test of a 30- by 30- by 6-inch wallette prepared from an air-gravel concrete developed at NBS. The specimen is being tested in the NBS 600,000-pound-capacity testing machine.

volume easily filled by water to total pore volume. The drying shrinkage of the air-gravel concretes did not differ significantly from values obtained for nonaerated sand-gravel concretes, ranging from 0.04 to 0.07 percent for 2- by 12-inch prisms after 180 days of drying.

Of 13 specimens of mix *A* and mix *C* concretes subjected to 100 cycles of laboratory freezing (0° F air) and thawing (70° F water), only one specimen (mix *C*) failed, at 40 cycles. Two specimens of nonaerated sand-gravel concrete failed at 60 cycles.

The thermal conductivity of these concretes, as determined by the NBS guarded hot-plate method, ranged from about 5 to 6 Btu/[hr ft^2 (° F/in.)]; a value obtained in tests of a nonaerated sand-gravel concrete was 9. A value often cited for conventional concrete is 12, but values ranging from 7 to 16 have been reported by various observers.

The air-gravel concretes developed at the National Bureau of Standards are considered experimental at the present time. The advantages in reduced density and thermal conductivity are appreciable but are gained only at a great sacrifice in strength. Greater advantages might be gained with higher cement contents and higher air contents, but the relatively high density of conventional aggregates imposes certain limits. The use of lightweight aggregates blended with dense aggregates in relatively high-air-content concretes may be a means of obtaining worthwhile reductions in density and thermal conductivity while maintaining low-order drying shrinkages.

For further technical details, see Air replaces sand in "no-fines" concrete, *by Rudolph C. Valore, Jr. and William C. Green, J. Am. Concrete Inst.* Proc. **47**, 833 (June 1951).

Small Continuous Furnace for Firing Printed Circuits

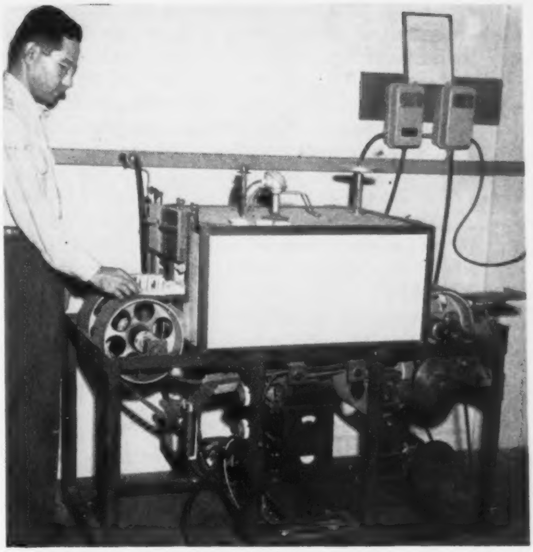
A small continuous-belt furnace has recently been designed and constructed by R. L. Henry and associates of the NBS engineering electronics laboratory. Smaller than commercially available continuous furnaces, such as those used in the glass industry, the new furnace is well suited for quantities somewhat too large to be efficiently handled by batch-type furnaces. While the unit was designed primarily for firing printed circuits to meet the needs of the printed circuit program sponsored at NBS by the Navy Bureau of Aeronautics, it could be equally valuable for firing or annealing moderate quantities of other materials, particularly in laboratory or pilot-plant installations.

A silver paint is used at NBS for printing electronic circuits. This printing fluid consists of finely powdered metallic silver, a suitable organic vehicle and solvent, and a flux. After a circuit pattern has been printed on a ceramic or glass plate by a stenciled screen process, the plate must be fired. The firing operation drives off the vehicle and solvent, activates the flux, and causes a partial sintering of the silver particles; the result is a firmly bonded metallic film of high conductivity. Although a batch-type furnace is adequate if only a few plates are being fired daily, a continuous furnace is more satisfactory for larger outputs.

The operation of the NBS furnace is quite simple. A continuously moving horizontal metal belt carries the material to be fired into the furnace at one end and delivers the fired product at the other end. Temperatures and belt speed are adjustable over a wide range. Normally, however, printed plates are fired at 1,350° F and spend 65 minutes in transit from cold input to cold output. Flat plates can be readily stacked six deep on the 4-inch-wide belt; this gives a firing capacity of about 800 square inches per hour at the usual belt rate.

The furnace proper is a tunnel, 31 inches long, with walls of insulating brick. A guillotine-type door at the input end of the tunnel is adjustable to the height of the load, while at the output end the load pushes through an asbestos curtain. The temperature rises gradually

Small continuous furnace constructed at NBS for the firing of printed electronic circuits. A batch of small ceramic chassis, on which circuit patterns have been printed with silver paint, is being loaded on the continuous belt. The belt, of variable speed, is ordinarily adjusted to deliver the fired chassis at the output end of the furnace in 65 minutes.



from the two ends of the furnace to a region of maximum temperature in the center. Three Nichrome-coil heating elements embedded in refractory cement are arranged to give this gradual rise, the center element being adjusted to a higher temperature than the two that flank it. The temperature of the central region can be controlled thermostatically to within 7 degrees of any temperature up to 2,000° F.

The continuous belt, woven of a high-temperature alloy, adequately resists corrosion at the furnace temperatures. An electric motor drives the belt through a speed-reducing train of gears, belts, and cone pulleys; suitable rearrangements of the train permit firing cycles ranging from 25 to 265 minutes.

The continuous furnace has proved highly useful in the NBS printed circuit laboratory. The furnace affords firing capacity fully adequate to the laboratory's needs, whereas the combined capacity of seven batch-type furnaces previously in use frequently proved inadequate. Yet floor space requirements of the new unit are modest, 26 by 54 inches. Utility of the furnace is enhanced by use of an automatic timer to turn it on before the beginning and off after the end of the working day.

Society for Experimental Stress Analysis Meets at NBS

The annual spring meeting of the Society for Experimental Stress Analysis was held at the National Bureau of Standards on May 16 to 18 in commemoration of the NBS Semicentennial. The five technical sessions were attended by approximately 200 engineers and physicists from points as widely separated as Seattle, Washington, and Caracas, Venezuela. Of the 20 papers presented, ten were concerned with the experimental determination of stress, while the other ten dealt with the wider field of experimental techniques in mechanics.

Two sessions were devoted to shock and vibration problems. At these sessions Professors N. J. Hoff and S. V. Nardo (Brooklyn Polytechnic Institute) outlined their studies of column action under dynamic load, which have thrown new light on the classical problem of column instability. William R. Campbell (NBS) described an ingenious technique for obtaining stress-strain curves at very rapid rates of loading from strain measurements on long rods subjected to longitudinal impact. He later demonstrated a giant "sling shot" machine, which has been constructed in the NBS engineering mechanics laboratory to increase the velocity of impact.

On May 17, members of the Society inspected various laboratories of the National Bureau of Standards and the Naval Ordnance Laboratory. After the tour, a banquet was held at which Dr. John H. Meier, President of the SESA, presented Dr. E. U. Condon, Director of NBS, with a scroll congratulating NBS upon its "outstanding accomplishments in the field of the physical sciences". In his presentation address, Dr. Meier emphasized the pioneer work of NBS in the field of experimental stress analysis over the past 30 years, mentioning in particular the Tuckerman optical strain gage, which has been the generally accepted means for precise strain measurements in this country since its development by Dr. L. B. Tuckerman of NBS about 20 years ago. The banquet was followed by a symposium on administration for scientists and engineers.

The last session, on May 18, was devoted to discussion of the measurement of residual stresses. Dr. H. R. Letner (Mellon Institute) described a simple yet extremely sensitive optical technique for measuring residual stresses at the surface of a metal specimen. The technique has shown that finishing procedures such as grinding may produce extremely high surface stresses that may reverse themselves within a few thousandths of an inch of the surface.

THE Declaration of Independence and the Constitution of the United States will be permanently preserved in sealed glass enclosures as a result of a joint program by the Library of Congress, the National Bureau of Standards, and the Libbey-Owens-Ford Glass Company. Scientific procedures for the permanent preservation of the original parchment documents of the Declaration of Independence and the Constitution of the United States have been recommended to the Library of Congress, custodian of the documents, by the National Bureau of Standards following a series of investigations at the NBS in cooperation with scientists of Libbey-Owens-Ford.

In accordance with NBS recommendations, the four leaves and the letter of transmittal of the Constitution and the leaf of the Declaration of Independence are to be sealed in air-tight envelopes, each envelope consisting of two panes of glass bonded to a metal frame. Each document-leaf will have its own enclosure and will rest upon special pure cellulose backing paper in an inert atmosphere of 99.99 percent pure helium having a controlled humidity. The enclosures will be exhibited in the shrine at the Library of Congress behind special filters that will shield the parchments from destructive light rays.

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The Declaration of Independence and the Constitution are unique and irreplaceable documents. Except for a short period when the exigencies of the Revolutionary War interfered, adequate measures of care have been taken in keeping with the scientific knowledge of the times. This care accounts for the present excellent condition of the documents. As the permanent preservation of these manuscripts for posterity is vital, even slight harmful effects that gradually appear must be avoided. Yet it is essential that these revered historical documents should continue to be on display to the American people in the shrine at the Library of Congress.

The principal considerations in the Bureau's analysis of the problem of preservation of the Declaration of Independence and the Constitution were the following:

First, the selection of a suitable inert gas is necessary because the atmosphere contains components that are destructive to parchment—in particular, oxygen.

Pure helium is passed through a pressure-reduction gage into the humidifying unit and then into the enclosure. The gas is allowed to flow through the enclosure for several days to replace the air with an inert atmosphere. E. C. Creitz (NBS) adjusts the flow prior to flushing the enclosure.

A facsimile document is placed enclos cellulose backing paper. Left : Dr. Director of Research, Libbey-O rd; A the Collections, Library of Cong nd Dr Organic Plastics Section nal B

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Second, the presence of either too much or too little moisture contributes to deterioration. It is thus necessary to determine and establish an atmosphere surrounding the documents that has just the right amount of moisture.

Third, a suitable enclosure is required, in part to retain the protective gas mixture and in part to afford a satisfactory means for viewing the documents.

Fourth, because it is difficult to ensure the air-tight nature of any enclosure, particularly over extended periods of time, a method of detecting and measuring gas leakage is required.

Fifth, it is necessary to provide a backing substance for the documents that will afford cushioning and that will compensate for any moisture absorption or desorption by the document as a result of temperature changes during the various seasons of the year.

Sixth, it is necessary to determine the harmful effects of light radiation on the documents and to determine the properties of a suitable filter that will eliminate practically all such damaging radiation.

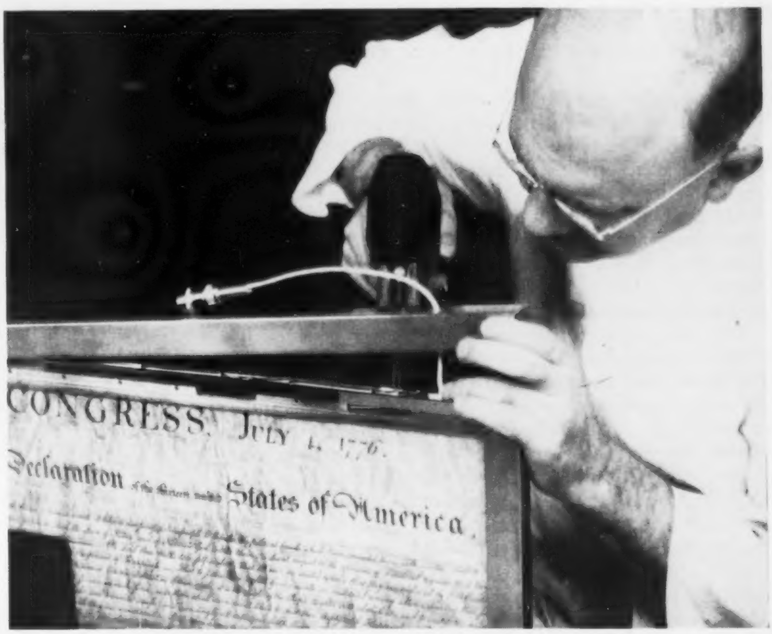
Inert Gas

Theoretically, a perfect vacuum would appear to provide the ideal environment for the parchments, but even a partial vacuum is difficult to maintain for any protracted period. A vacuum would also create a mechanical problem, for the enclosure and the bond would be subject to considerable stress.

An inert gas was selected for the preservation of the documents primarily because such a gas is not chemically active and therefore will not enter into chemical reaction with the parchment or ink, as would oxygen. Moreover, an inert gas does not support life, and will protect the documents against insects and other living organisms. Of the inert gases available, the NBS has selected helium. Helium is available from the U. S. Bureau of Mines in a very pure state—impurities of less than 0.01 percent—and free of oxygen. It has a relatively high thermal conductivity compared to air, which makes it easy to detect the leakage of air into the enclosure.

placed enclosure frame on top of a pure Left : Dr. Roy W. Wampler, Assistant bbey-O rd; Alvin W. Kremer, Keeper of f Cong nd Dr. G. M. Kline, Chief of the Section nal Bureau of Standards.

After all holes have been sealed, the bronze frame is fitted to the enclosure. Wires from the reference cells and two cells inside the enclosure are connected to a line that passes through the frame and terminates in a socket. E. C. Creitz solders the lead from a reference cell to the external lead.



Following the assembly of all enclosure elements, the lead strip is soldered to the glass plates. This operation, one of the most critical in the entire sealing procedure, is being performed by Louis Gilles of the Libbey-Owens-Ford Glass Company.

Moisture Problem

The presence of large amounts of moisture leads to deterioration of documents by causing a loss in strength of the parchment or paper. Such materials in humid atmospheres are subjected to the danger of attack by microorganisms that do not require air but that do require high moisture environments. On the other hand, too little moisture leads to brittleness and cracking, and eventually to a breaking up of the parchment.

Research at the NBS indicates that the relative humidity of the helium should be between 25 and 35 percent at room temperature. This humidity is found to be best for the long-range durability of collagen, a protein material, which is the basic constituent of the parchment of the documents. Studies by the Bureau reveal that a relative humidity greater than 85 percent leads to deterioration of the parchment. A relative humidity less than 25 percent dehydrates the protein molecules of the parchment, causing brittleness and cracking.

Transparent Enclosure

The enclosures for the documents must be air-tight, transparent, and made of chemically inert materials. They must not be fragile. The requirements for transparency and chemical stability are of such importance that the National Bureau of Standards decided that a glass enclosure should be used.

Two considerations determined the Bureau's choice in selection of the type of glass enclosure; first, the need for glass plates that would be as uniformly transparent as possible, and second, the need for an enclosure whose components could be assembled and sealed into an air-tight structure without damaging the documents. Here the principal consideration was the effect of heat on the documents. Any process that involves the sealing of materials within an air-tight enclosure requires the use of heat at some stage in the operation. It was thus necessary to select the process that required a minimum of heat and that precluded the transferrence of a possibly harmful amount of heat to the documents.

The danger of damage to the documents as a result of breakage of the glass is minimized by three factors: First, the care that must be accorded the documents affords a very large measure of protection. Second, an unusually tough tempered glass has been selected. Third, the presence of special backing paper (produced by the NBS) and the cover plate will also minimize the chance of injury to the documents in the event of breakage of the enclosure.

The National Bureau of Standards determined that double-glazed panels made commercially as insulating windows would meet these requirements. The Libbey-Owens-Ford Glass Company agreed to cooperate in the project by preparing Thermopane enclosures for the documents.

The enclosures consist of two rectangular panes of tempered plate glass separated $\frac{3}{8}$ inch by a $\frac{1}{16}$-inch-thick lead strip that is set in approximately $\frac{3}{8}$ inch from the edges of the glass panes and that completely encircles the enclosure. The two panes of glass have a special metallic coating applied on them where they make contact with the lead strip. This coating makes it possible to bond the lead strip to the glass panes by solder, thus completely sealing the interior cavity from the outside atmosphere. A bronze bracket $\frac{7}{16}$ inch wide is inserted inside of the enclosure to frame the document completely and to hold in place the glass cover plate that rests on the document to keep it flat.

A trial sealing of a facsimile of the Declaration of Independence in such a glass enclosure was conducted at the National Bureau of Standards in June 1950. This test provided information on the detailed steps in the sealing process and on the performance of equipment needed for the original documents. Following the trial sealing, the National Bureau of Standards conducted tests on the air-tightness of the enclosure. The enclosure and sealing method were found to be satisfactory.

Leak Detector

The construction of an enclosure that will remain air-tight over long periods of time is a formidable problem. The difficulty in retaining the properly humidified helium intact within the enclosure and in excluding atmospheric gases is twofold. Any handling of the enclosures or changes in temperature may cause stresses in the bonding components between the two glass plates of the enclosure. There is some chance that such stressing might produce minute openings in the bond.

Moreover, matter, in spite of its apparent imperviousness to change, is dynamic in nature by virtue of its atomic structure. Thus, in the course of time, there are possible changes in the constitution of the bond—particularly those changes resulting from seasonal temperature variations—that can lead to minute openings. If the presence of such openings is known, it is a relatively simple matter to find and reseal the openings long before any harmful change in the helium content of the enclosure occurs. The problem is to provide a suitable detector.

The National Bureau of Standards selected a thermal-conductivity type of gas analyzer as the leak detector. This detector is based upon the fact that each gas is unique in its ability to transfer heat. Any change in the composition of a gas can be observed by measuring the change in its thermal conductivity.

The equipment developed at the Bureau is small enough that the detector can be built permanently into the enclosure, and it is simple enough that observations can be made either continuously or as frequently as desired without removing the enclosure from the Shrine. The leak detector consists of measuring cells, which are sealed within the enclosure, and of certain components comprising the external leak detector instrument. The basis of leak detection is the change with temperature in the resistance of a thin platinum wire in each of the measuring cells. Thus, if electric current is passed through such a wire when it is surrounded by gas having a low thermal conductivity, the heat generated in the wire by the current cannot readily escape by transfer to that gas. This leads to a rise in temperature of the wire and its resistance becomes correspondingly higher. If the instrument is set to read zero in an atmopshere of pure helium, leakage of air (which has a lower thermal conductivity) into the helium atmosphere will be detected by the increase in the resistance of the platinum wire.

For each enclosure, four thermal conductivity cells are involved. Two of these are sealed within each enclosure; two are located in the channel along the edge of the enclosure.

The thermal conductivity cell consists of a filament of 0.001-inch diameter platinum wire wound into a helix and supported on a pair of Kovar wires, which in turn are sealed into a 0.25-inch Kovar tube by means of a glass bead. The assembly is slipped inside of a 0.25-inch (inside diameter) copper tube 1.5 inches long and soldered in place so that the position of the filament is fixed in relation to the tube. Four of these cells in each enclosure are connected to form the equal arms of a Wheatstone bridge. Two of the cells, in opposite arms of the bridge, are filled with helium and sealed off for use as reference cells. The other two cells are mounted inside the enclosure and are used as measuring cells. Comparison of the resistances of each pair of cells indicates whether any change has occurred in the composition of the gas within the enclosure.

The thermal conductivity cells were developed at the Bureau by E. C. Creitz, of the gas chemistry laboratory. Much of the development is based on investigations of thermal conductivity made by E. R. Weaver, Chief of the gas chemistry laboratory.

Backing Paper

Backing paper for the documents is necessary for several reasons. First, as the temperature changes with the seasons of the year, the relative humidity within the enclosure will change. To act as a compensating reservoir for moisture, particularly if the enclosures are subject to rapid temperature change, suitable backing paper is desirable.

In addition, no matter how stable the conditions attained within the enclosure, there will be minute movements of the parchment. To provide for such motion, a resilient, cushioning backing is necessary. Finally, some backing substance that affords protection of the Documents in the event that the enclosure is seriously damaged is desirable.

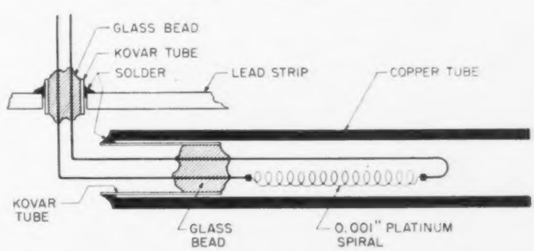
These requirements for backing and the additional requirements of purity and chemical stability led to the choice of a pure cellulose for the backing material. The proper composition of the cellulose was determined by the National Bureau of Standards, and sheets of such cellulose were prepared in the NBS experimental paper mill.

Lighting the Documents

One of the causes of deterioration of documents is light radiation, which induces chemical reactions in a variety of substances. The effect of light radiation depends, in general, upon the kind of radiation and the nature of the substance involved. Studies at the National Bureau of Standards revealed that damage to documents like the Declaration of Independence and the Constitution is caused largely by ultraviolet light and by visible blue and violet light.

Radiant energy from incandescent-filament lamps and from diffused daylight is incident on the cases at

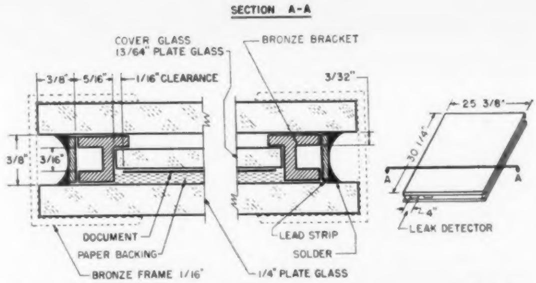
CROSS SECTION OF THERMAL CONDUCTIVITY CELL



Thermal conductivity cell developed at NBS for preservation of the documents. The small filament consists of a fine patinum wire, wound into a helix and supported on a pair of Kovar wires which, in turn, are sealed in the Kovar tube by a glass bead. The assembly is soldered in place in the copper tube thus fixing the posit:on of the filament. Current passing through the spiral causes an increase in temperature with a corresponding increase in electrical resistance. This increase is greater in air than in helium.

the present location of the Shrine, although no direct sunlight strikes the cases. There has been installed in the cover door of each case of the Shrine a laminated glass prepared by the American Window Glass Company with a plastic interlayer in which the necessary light-absorbing material has been incorporated. The Eastman Kodak Company has cooperated by supplying the necessary large yellow cellulose acetate sheet required for this project. The yellow acetate sheet is similar in optical properties to a Wrattan 4 filter and absorbs completely in the range from 310 to 430 millimicrons. Both sides of the filter were coated with polyvinyl butyral to facilitate lamination with glass.

For further technical details, see Preservation of the Declaration of Independence and the Constitution of the United States, *NBS Circular 505, U. S. Government Printing Office, Washington, D. C. Price 15 cents.*



Section diagram of the glass enclosure recommended for preservation of the documents. The backing paper and cover glass position the document, the bronze bracket separates the glass plates from the assembly, and the lead strip soldered to the glass completely seals the document from the outside atmosphere.

Oil Film Thickness Indicators for Sleeve-Type Bearings

In studies of engines and engine lubricants, it is often desirable to measure clearances between shafts and sleeve- or journal-type bearings during operation. However, it is usually rather difficult to obtain such measurements without affecting the operation, particularly at high speeds. A method recently developed by M. L. Greenough and associates of the NBS electronic instrumentation laboratory for the Navy Bureau of Ships appears to offer a satisfactory solution of the problem. The heart of the new system is a mutual-inductance type of electrical distance-measuring element; variation of the distance of the rotating shaft from two small fixed coils results in a readily measurable variation in the coupling between the coils.

Development of the gage centered around the problem of measuring film thickness in a 6-inch bearing with a radial clearance (difference in radius of shaft and bearing) of about six thousandths of an inch (6,000 microinches). Anticipated maximum rotational speeds were in excess of 10,000 rpm; hence, the gage was designed to make no physical contact with the shaft. Operation in lubricating oil at a temperature of 200° F was another requirement.

Three successful variations of the device have been developed. The models differ in the type and number of probes used, in sensitivity, in suitability for measuring vibratory conditions, and in type of indicating device. A cathode-ray tube is used with one model to provide a continuous picture of shaft displacement, while the other models give distance indications on a dial or meter. Sensitivity is ample; a distance change of as little as 10 microinches, less than a thousandth of the difference in diameter between shaft and bearing, may be detected. In the cathode-ray-tube model a small displacement of the shaft causes a displacement 150 times as great on the face of the cathode-ray tube, and this is by no means the maximum magnification attainable with the system.

In general, measurement of the distance of the shaft from a single probe will not define the shaft-to-bearing distance at all points, even though the shaft be perfectly rigid. From two to six probes are therefore used in the various NBS models. The probes are fastened rigidly to the bearing under study at various locations just outside the point at which the shaft enters the bearing.

Air-core probes at radio-frequency are used in one indicator model (Model 1), while iron-core probes at audio frequency are used with the others (Models 3 and 4). Although the air-core-probe system was originally developed at NBS for oil-film thickness measurements, the same principle has been used in the NBS electronic micrometer and micromanometer [1]. The miniature iron-core type, however, is an outgrowth of work by previous investigators on oil-film thickness.

The two types of probe have much in common. Each probe consists of a pair of small coils—a primary and a secondary—mounted close to each other and close to, but not touching, the surface of the shaft. An alternating current applied to the primary induces in the secondary a voltage, dependent on the mutual inductance or coupling between the coils. Because of the effect of the nearby metal shaft on the electrical field of the coils, the coupling, and hence the output voltage, varies with changes in shaft-to-coil distance. The readily measurable relation between primary current and secondary voltage is thus an index of shaft-to-coil distance, and indicating instruments may be calibrated in terms of shaft-to-bearing distance.

In the air-core probes, which operate at a frequency of the order of 2.5 megacycles, the coils are concentric and approximately coplanar. The nearby metal shaft acts as a shield; the closer the shaft to the probe, the less the coupling between the coils. This shielding action—and, hence, the sensitivity of the arrangement to changes in distance—is optimum if the metal sur-

face is nonmagnetic. For this reason it is desirable, in test installations using the air-core probe, to electroplate the shaft with a thin band of copper centered under the probes.

The coils of the iron-core probes, which are operated at about 2,000 cycles, are wound on the legs of a U-shaped form. The nearby steel shaft increases the magnetic flux through the coils; thus, with the iron-core probes, the closer the shaft to the probe the greater the coupling between the coils.

Each of the two types of probe has its advantages and limitations. The iron-core technique is better suited to installations where maximum sensitivity is desired, and furthermore does not require copper plating of the steel shaft. The radio-frequency air-core probes, on the other hand, make possible accurate observations of high-frequency shaft vibration; these are not possible with the low-frequency iron-core method. The air-core system is also more nearly linear: the input-output ratio is more closely proportional to distance.

Model 1, the air-core unit, is used with a cathode-ray tube to give a polar diagram of the displacement of the center of the shaft from the center of the bearing. This is accomplished by means of four probes spaced at 90-degree intervals and supplied with constant current. The rectified output of each probe is connected to a corresponding one of the four deflection elements, similarly arranged in quadrature, of the cathode-ray tube. The position of the electron beam at any instant is thus the resultant of the four rectified probe output voltages. When the shaft is exactly centered, the electron beam (necessary calibration factors having been introduced electrically) is also exactly centered. When the shaft is displaced from center, both the direction and amplitude of this displacement are depicted on the face of the tube. Should any shaft vibration be present, its amplitude and plane can be readily and accurately observed. Also, any distortion of the bearing from perfect circularity—usually the result of unequal temperature distribution—can be detected. Although in normal operation all four probes are connected to the deflection plates, a selector switch permits examination of each probe separately, if desired.

Models 3 and 4, the iron-core models, are used with voltmeters rather than cathode-ray tubes. More sensitive than Model 1, both Model 3 and Model 4 are well suited to precise distance measurements in a bearing-test installation after Model 1 has provided an over-all picture.

NBS oil-film thickness indicator, Model 1, installed on a test sleeve-type bearing. Air-core mutual inductance probes, each consisting of a primary and a secondary coil, are mounted rigidly on the shaft. When an alternating current is applied to the primary coil, the voltage induced in the secondary coil varies with the distance of the shaft from the coil. This voltage may thus be used to give an indication of the clearance between shaft and bearing on the cathode-ray tube, right. (Photo courtesy U. S. Naval Engineering Experiment Station)

In Model 3, which uses two probes, the 2,000-cycle primary input is automatically adjusted to the level required to give a constant secondary output. The adjusted input is indicated on a meter calibrated in distance units.

Six probes are used with Model 4, which is even more sensitive than Model 3. In Model 4, primary current is held constant while secondary voltage is measured with a bridge circuit of adjustable sensitivity. The bridge circuit is balanced by adjusting a potentiometer dial having an approximately linear scale calibrated in distance units. Model 4, which also uses fewer tubes (three instead of seven or eight) and is probably the most reliable and accurate of the series, is the culmination of the present NBS-BuShips oil-film-thickness measurement program.

[1] *Model 1, the first version developed, is described in detail in AIEE Tech. Paper 48–96 (December 1947),* Oil-film thickness indicator for journal bearings, *by M. L. Greenough. For application of the principle to the electronic micrometer, see NBS Tech. News Bulletin* **31**, *37 (1947); and to the micromanometer, NBS Tech. News Bulletin* **34**, *137 (1950).*

Horological Institute Meets at NBS

The thirtieth annual convention of the Horological Institute of America was held at the National Bureau of Standards on May 13 to 15 in commemoration of the NBS Semicentennial. Topics of current interest to the watchmaking industry were presented by a number of leaders in the field.

The first session was opened by A. S. Rowe, President of the Institute, who reviewed the work of the HIA during the past year. An interesting lecture on the marine chronometer, by F. E. Peters and C. G. Smith, was followed by a discussion period. Alvin Levine (Watchmakers of Switzerland, Inc.) presented a paper on "Merchandising the watch repair department", and

Donald DeCarle, FBHI, and Dr. A. I. Rowlings gave short, informative talks.

The May 14 session began with a welcoming address by Dr. E. U. Condon, Director of NBS, who gave a brief resume of the progress at NBS over the past 50 years. R. E. Gould, Secretary of the HIA, then presented Dr. Condon with a scroll congratulating NBS on its fiftieth anniversary and citing NBS "accomplishments in establishing and maintaining time standards of high precision." A lecture by Dr. J. A. Van Horn (Hamilton Watch Co.) on "Physics in the watch industry" followed. J. L. K. Sorensen described the activities of the Minneapolis Watchmakers' Guild, and Mr. DeCarle gave a short talk on the activities of the British Horological Institute. A watchmakers' forum, which took place during the afternoon, proved both interesting and instructive. At the convention dinner, held at the Wardman Park Hotel that evening, Norman Leach (Canadian Jewelers' Institute) gave an address entitled "When watchmakers mean business".

On May 15, an illustrated lecture, "Recent developments in the determination of time", was delivered by Paul Sollenberger (U. S. Naval Observatory). In a lecture on "Hairspring vibrating", H. B. Fried, well-known author-lecturer, discussed all forms of hairspring manipulation; selection of proper hairspring; colleting, overcoiling, vibrating, and studding. After an illustrated talk by Dr. Harold Lyons (NBS) on the Atomic Clock, the convention ended with a tour of NBS laboratories.

Radiometery of Fluorescence

Within the past 15 years the use of fluorescent lamps for general and decorative lighting has increased to such an extent that the incandescent lamp now has a serious competitor. The extensive adoption of fluorescent lighting for household, recreational, commercial, and industrial uses has at the same time aroused much interest in its relationship to colors, whether it be that of a paint, a dyed fabric, a chemical reaction, or even a person's facial appearance. A food, for example an egg, may appear unappetizing under a fluorescent lamp if its color is improperly matched with daylight. The spectral quality of the radiant energy from the lamp determines its usefulness in a particular application. Experiments at the National Bureau of Standards, conducted by Ralph Stair, have resulted in the development of a method and associated equipment for use in the precise evaluation of the spectral energy distribution of fluorescent lamps.

Commercial fluorescent lighting devices are essentially mercury-vapor lamps containing a small amount of argon gas to facilitate starting. The electrical characteristics, current density, vapor pressure, and voltage are so regulated that the resultant discharge produces a maximum amount of energy in the ultraviolet region of the electromagnetic spectrum centered at 253.7 millimicrons. The ultraviolet energy activates the phosphor with which the inside of the tube or bulb is coated, and the activated phosphor, in turn, fluoresces, emitting energy in the visible region. In general, the spec-

NBS-modified Farrand double quartz-prism spectrometer used to measure the relative spectral distribution of fluorescent lamps. The light from a lamp (left) is modulated at 510 cycles per second by a motor-driven sector disk before entering the spectrometer. Owing to the finite width of the spectrometer slits, the spectrum is split into wavelength-widths of only a few millimicrons. The output of the photoelectric tube-detector (extreme right of the spectrometer) is fed through a tuned amplifier to a recorder (right background), which is synchronized with the wavelength selector drive on the spectrometer.

tral composition of the emitted energy depends on the particular phosphor that is used.

The NBS investigations of spectral energy distribution have therefore been concentrated on the sharp-line spectrum of mercury superimposed on the continuous spectrum produced by the fluorescing phosphor. Usually the inner coating of the tube is composed of a combination of two or more phosphors. Such a mixture of materials produces peaks in the visible spectrum at different wavelengths, which appear as an addition of two or more continuous spectra.

Radiant energy is measured in terms of the amount of energy flowing from the source per unit area per unit time at a specified distance from the source. Measurements of relative spectral value are made in terms of some arbitrary wavelength reference in the spectrum. When evaluating the relative spectral energies, special consideration must be given to the fact that the complete spectrum consists of the mercury emission lines superimposed upon the continuous fluorescent spectrum. Variations in spectral output are produced by the various types of phosphors employed and also by different glass envelopes. The glass ordinarily used in illuminating fluorescent lamps is opaque to wavelengths shorter than 300 millimicrons. A sunlamp, because of unusual requirements as to energy distribution, represents an exceptional case. A feature of the design of such lamps is that the envelope must transmit energy down to a wavelength of 280 millimicrons. In this particular case, the phosphor produces a radiant energy peak at 300 to 320 millimicrons—wavelengths in the ultraviolet region and out of the range of visible detection.

Radiant energy and wavelength are measured in the Bureau's studies on an NBS-modified Farrand double quartz-prism spectrometer. The light from a source is initially modulated at 510 cycles per second by a motor-driven sector disk. The modulated beam of light is split into its components as it passes through the motor-driven spectrometer and falls on a phototube at the end of the spectrometer path. As the spectrum is scanned, the phototube detector is exposed to radiant energy of continuously changing wavelength. Owing to the finite width of the spectrometer slits, wavelengths covering a spectral region only a few millimicrons wide are received at a given instant. The output of the phototube, which responds to the magnitude of the energy of each narrow spectral region, is fed to a tuned amplifier designed for maximum linearity of response and negligible zero drift. Finally, the amplified signal is applied to a continuous-line recorder. The motor drive of the recorder is synchronized to the wavelength-selector drive on the spectrometer so that the wavelength of each narrow spectral region and the corresponding radiation magnitude detected by the phototube are recorded simultaneously.

The spectrometer is calibrated by means of a standard tungsten-filament lamp. The precise evaluation of the energy distribution of this lamp is based on its operating temperature and a knowledge of the spectral emissivity of tungsten.

For further technical details, see Photoelectric spectroradiometry and its application to the measurement of fluorescent lamps, *by Ralph Stair, NBS J. Research* **46,** 437 (1951) *RP*2212.

Acoustical Society Meets at NBS

More than 200 physicists, engineers, and architects attended the meeting of the Acoustical Society of America at the National Bureau of Standards on May 10, 11, and 12, 1951. At the Society's banquet, the president, Professor Philip M. Morse, presented a scroll to Dr. E. U. Condon, NBS Director, in commemoration of the semicentennial of the Bureau.

The 3-day meeting was highlighted by an architectural acoustics symposium that was jointly sponsored by the American Institute of Architects and the Society. A large attendance heard leaders in the field, including A. London (NBS), C. Harris and C. T. Molloy (Bell Telephone Laboratories), Benjamin Smith (Voorhees, Walker, Foley, and Smith), V. O. Knudsen (University of California at Los Angeles), R. B. Newman (Massachusetts Institute of Technology), A. T. Pickles (Building Research Station, England), and R. H. Bolt (Massachusetts Institute of Technology). In addition to reporting recent developments in architectural acoustics, the speakers stressed the need for continued interchange of ideas between architects, engineers, and physicists.

Other sessions were devoted to transducers and instruments for acoustics, underwater sound, ultrasonics, contributed papers on architectural acoustics, psychoacoustics, and sound wave fields and nonlinear effects. The Society and its guests toured the Bureau's Laboratories, and attended an open house in the NBS Sound Laboratory.

Standard Fineness Sample

The National Bureau of Standards is now issuing a new standard fineness sample for the calibration of instruments used in testing portland cements and related materials. The new sample, Portland Cement Standard Fineness Sample 114G, is applicable to the Wagner turbidimeter, the Blaine air-permeability fineness meter, and the No. 325 sieves.

NBS first began the issuance of standard fineness samples for sieve calibration in the portland cement industry over 35 years ago. With the development of other instruments for determining the fineness of portland cement, new standard fineness samples have been issued from time to time for the calibration of these instruments. Whereas the various devices for measur-

ing fineness can generally be calibrated from the constants of the instruments, the use of standard samples makes the calibration easier and brings the results of tests in different laboratories into closer agreement.

Orders for NBS Portland Cement Standard Fineness Sample 114G should be sent to the *National Bureau of Standards, Washington 25, D. C.*, accompanied by payment in advance. The cost of a 12-gram sample is $2.50. Remittances should be payable to the *National Bureau of Standards.* When ordering, specify both name and number of the sample.

A revised list of Standard Samples and reference standards issued by the National Bureau of Standards has also been published as a Supplement to NBS Circular 398. Copies of the supplement can be obtained from the *Superintendent of Documents, Government Printing Office, Washington 25, D. C.*, at 20 cents each.

Publications of the National Bureau of Standards

Periodicals

Journal of Research of the National Bureau of Standards, volume **47**, number 1, July 1951 (RP2220 to RP2227, incl.). 40 cents.

Technical News Bulletin, volume **35**, number 7, July 1951. 10 cents.

CRPL–D83. Basic Radio Propagation Predictions for October 1951. Three months in advance. Issued July 1951. 10 cents.

Research Papers

Reprints from Journal of Research, volume 46, number 6 June 1951

RP2212. Photoelectric spectroradiometry and its application to the measurements of fluorescent lamps. Ralph Stair. 10 cents.

RP2213. Penetration and diffusion of X-rays. Calculation of spatial distributions by polynomial expansion. Lewis V. Spencer and U. Fano. 10 cents.

RP2214. A study of fatigue in metals by means of X-ray strain measurement. John A. Bennett. 10 cents.

RP2215. On the mean duration of random walks. Wolfgang Wasow. 10 cents.

RP2216. Effect of chromium plating on the plastic deformation of SAE 4130 steel. Hugh L. Logan. 10 cents.

RP2217. Stochastic processes and dispersion of configurations of linked events. Chan-Mou Tchen. 10 cents.

RP2218. Heat of combustion and formation of cyanogen. John W. Knowlton and Edward J. Prosen. 10 cents.

RP2219. Behavior of bromophthalein magenta E (tetrabromophenolphthalein ethyl ester) with organic bases and its bearing on the Brønsted-Lowry and Lewis concepts of acidity. Marion Maclean Davis and Hannah B. Hetzer. 10 cents.

Circulars

C398 (Supplement). Standard samples and reference standards issued by the National Bureau of Standards. 20 cents.

C509. Bibliography of books and published reports on gas turbines, jet propulsion, and rocket power plants. Ernest F. Fiock and Carl Halpern. (Supersedes Circular 482). 20 cents.

Handbooks

H47. Recommendations of the international commission on radiological protection and of the international commission on radiological units 1950. 15 cents.

Miscellaneous

M200. Annual report of the National Bureau of Standards, 1950. 50 cents.

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Comparing outputs from precision time standards. J. M. Shaull and C. M. Kortman. Electronics (330 West Forty-second Street, New York 18, N. Y.) **24,** No. 4, 102 (1951).

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International exchange of scientific information. Wallace R. Brode. Chem. & Eng. News (1155 Sixteenth Street, NW., Washington 6, D. C.) **28,** 4332 (1950).

Fixture unit ratings as used in plumbing system design. H. N. Eaton and J. L. French. Housing Research Paper No. 15, Housing and Home Finance Agency. (Available only from the Supt. of Documents, Government Printing Office, Washington 25, D. C., at 15 cents a copy).

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Current views on colour blindness. Deane B. Judd. Documenta Ophthalmologica (The Hague, Netherlands) **3,** 251 (1949).

Microwave spectra of deutero-ammonias. Harold Lyons, L. J. Rueger, R. G. Nuckolls and M. Kessler. Phys. Rev. (57 East Fifty-fifth Street, New York 22, N. Y.) **81,** 630 (1951).

Motion in the solar atmosphere as deduced from radio measurements. Grote Reber. Science (1515 Massachusetts Avenue, NW., Washington 5, D. C.) **113,** 312 (1951).

Net heat of combustion of AN-F-58 aircraft fuels. Simon Rothberg and Ralph S. Jessup. Ind. and Eng. Chem. (1155 Sixteenth Street, NW., Washington 6, D. C.) **43,** 981 (1951).

The interpretation of radar echoes from meteor trails. J. Feinstein. J. Geophys. Res. (4241 Broad Branch Road, NW., Washington, D. C.) **56,** No. 1, 37 (1951).

A circuit for simultaneously recording the range, amplitude, and duration of radar-type reflections. V. C. Pineo and R. C. Peck. Rev. Sci. Instr. (57 East Fifty-fifth Street, New York 22, N. Y.) **22,** 112 (1951).

A source of error in radio phase measuring systems. R. Bateman, E. F. Florman, and A. Tait. Proc. IRE (1 East Seventy-ninth Street, New York, N. Y.) **39,** 436 (1951).

Wide-range resonators for VHF and UHF. G. Franklin Montgomery and Peter G. Sulzer. Electronics (330 W. Forty-second Street, New York 18, N. Y.) **42,** No. 5, 200 (1951).

An incremental delay pulse generator. G. Franklin Montgomery. Electronics (330 W. Forty-second Street, New York 18, N. Y.) **42,** No. 2, 218 (1951).

Modified resonant circuits match impedances. Peter G. Sulzer. Tele-Tech (480 Lexington Avenue, New York 17, N. Y.) **9,** No. 11, 41 (1950).

U. S. GOVERNMENT PRINTING OFFICE: 1951